Validation of Real-Time Instrumentation System for Gait Adjustment

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Motivation

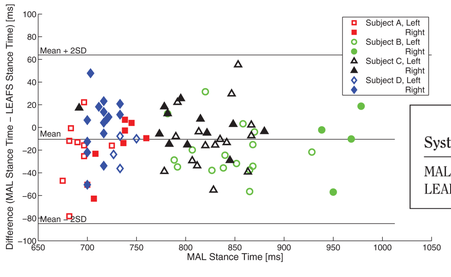
Asymmetric gait can lead to osteoarthritis, osteoporotic changes, and excessive metabolic costs. The Adaptive, Real-Time Instrumentation System for Tread Imbalanace Correction (ARTISTIC) was developed to provide real-time gait feedback through audio, visual, and haptic cues. These cues are meant to aid in correcting asymmetric gait.

Figure 1. ARTISTIC insole and instrument box

The ARTISTIC integrates a microcontroller, Bluetooth receiver and Android smartphone to process gait data and send feedback to the user. The purpose of this research is to validate the effectiveness of the ARTISTIC in assisting subjects whose gait has been characterized as abnormal. Improvements on the design of the ARTISTIC will be made to make the system more intuitive and comfortable.

Verification

The ARTISTIC must be verified against equipment in a motion analysis lab (MAL). The Lower Extremity Ambulation Feedback System (LEAFS), a predecessor to the ARTISTIC, was verified against equipment in the motion lab at Shriners Hospital in Salt Lake City, UT[1]. It was shown that the LEAFS was capable of identifying stance time with a low-bias error. A similar verification for the ARTISTIC will confirm its accuracy in determining stance time asymmetry.



System	Stance time difference (prosthetic-intact)	95% TI	p
MAL	−63.8 ms	−83.0 to −44.6	<0.001
LEAFS	−66.3 ms	−87.4 to −45.2	<0.001

Figure 2. Verification of ARTISTIC predecessor against motion analysis lab equipment

Testing

Feedback Testing:

Three methods of feedback will be tested and compared to determine an optimal feedback protocol:

- Negative Feedback: relays cues about prior steps
- Positive Feedback: relays cues before step is taken
- Hybrid Feedback: combines positive and negative

It is hypothesized that negative feedback will work best for subjects with slight asymmetry and that positive, more aggressive feedback will be most effective for larger gait asymmetries.

Test Subjects:

Testing will be conducted on subjects with lower limb prosthetics. To make the study more robust, subjects with both below and above the knee prosthetics will be selected. Testing will also compare response time to age of subject to confirm that the ARTISTIC is an intuitive system.

ID #	Control		First Trial			Second Trial	
	Ratio mean ± SD	Feedback	Target	Ratio mean ± SD	Feedback	Target	Ratio mean ± SD
1	1.06 ± 0.03	Visual	1.5	1.22 ± 0.09	Visual	0.5	0.71 ± 0.10
2	1.01 ± 0.11	Visual	1.5	1.21 ± 0.08	Visual	0.5	0.81 ± 0.11
3	0.86 ± 0.10	Audible	0.5	0.87 ± 0.12	Audible	1.5	0.90 ± 0.10
4	1.03 ± 0.04	Visual	0.5	0.65 ± 0.09	Visual	1.5	1.24 ± 0.08
5	1.18 ± 0.04	Visual	1.5	1.43 ± 0.15	Visual	0.5	0.62 ± 0.15
6	0.99 ± 0.10	Audible	0.5	0.59 ± 0.13	Audible	1.5	1.36 ± 0.25
7	0.95 ± 0.02	Visual	1.5	1.36 ± 0.22	Visual	0.5	0.64 ± 0.10
8	0.89 ± 0.08	Vibrotactile	0.5	0.96 ± 0.17	Vibrotactile	1.5	0.89 ± 0.15
9	0.79 ± 0.08	Vibrotactile	1.5	1.38 ± 0.39	Vibrotactile	0.5	0.96 ± 0.14
10	0.99 ± 0.06	Visual	0.5	1.11 ± 0.32	Visual	1.5	1.29 ± 0.19
11	0.98 ± 0.12	Visual	1.5	1.27 ± 0.28	Visual	0.5	0.69 ± 0.31
12	1.13 ± 0.06	Vibrotactile	1.5	1.30 ± 0.13	Vibrotactile	0.5	0.75 ± 0.13

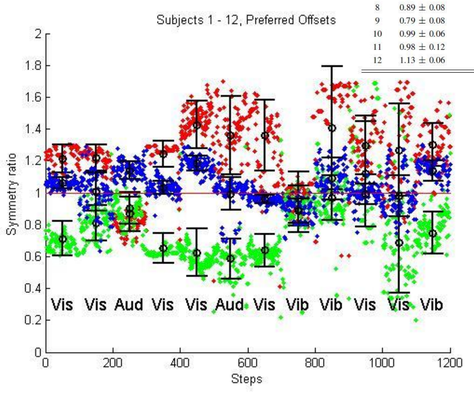


Figure 3. Results of preferred negative feedback methods

Previous testing of the ARTISTIC showed that subject selection of a preferred feedback cue was successful in causing real-time gait disturbance in subjects with normal gait. This research will validate the ARTISTIC for real-time gait correction in subjects with gait abnormalities, preferably with lower limb prosthetics. Improvements will be made to the system to make feedback more intuitive. The Android application will also be expanded to include additional functionality for feedback types.

Design Improvements

Improvement of the ARTISTIC design will include:

1) Adding vibro motors to ankle box for improved haptic feedback.
2) Reducing box size and adding comfortable straps to improve aesthetics.
3) Utilizing the 2-way Bluetooth receiver to send and receive data from the Android

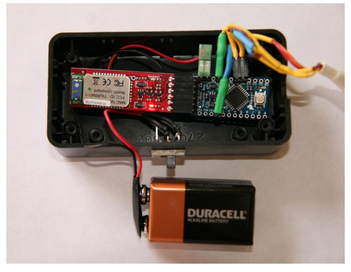


Figure 4. Instrument box with Arduino controller and Bluetooth receiver

Figure 5. Arduino application screens for feedback modes

Conclusion

Results from this research will provide insight into the best form of feedback (audio, visual, or haptic) for gait asymmetry correction. Positive, negative, and hybrid feedback will also be examined. The ARTISTIC will be shown to be an effective and reliable real-time gait correction tool.

Acknowledgments

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References

1. Bamberg SJM, Carson RJ, et al. The Lower Extremity Ambulation Feedback System for Analysis of Gait Asymmetries: Preliminary Design and Validation Results. *J Prosthet Orthot.* 2010; 22:31-36